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GLACIAL MARKS ON THE PACIFIC AND ATLANTIC COASTS COMPARED.

BY A. S. PACKARD, JR.

WHILE in Europe one can readily interpret the ancient moraines and other ice marks by reference to existing glaciers with their moraines, ice grooves, and scratches, the American geologist is usually forced to make a long journey to Switzerland, the Pyrenees, or to Norway in order to observe such phenomena, now to be seen on an extended scale only in Arctic America and in Greenland. However, the recent discovery by Mr. Clarence King of a few small glaciers in the Sierra Nevada of California has, with the observations of others, shown, what was quite unsuspected a few years ago, that not only the Rocky Mountains but the Sierra Nevada have been the seat of extensive glaciers, which in the Sierra Nevada descended to a point between two and three thousand feet above the sea, or as low as five or six thousand feet in the Rocky Mountains. We had followed up these discoveries with much interest, and made during our entomological journeys cursory observations upon ancient glaciers and rounded rocks in the Rocky Mountains in 1875, and again during the early part of the past summer in Montana and parts of adjoining Territories. In the course, however, of an extended journey through Middle and Northern California, portions of Oregon, Washington Territory, and Vancouver Island, undertaken in the interests of the United States Entomological Commission, I was enabled from the stage-coach, or on horseback, or in the course of my entomological walks, to observe certain more salient points, which some experience in past years in the study of surface geology in Switzerland and Norway, as well as in New England and Labrador, rendered of a comparative nature and proved of great personal interest. Indeed, I have been struck with the remarkable parallelism between all the more general glacial phenomena, whether observed in the Old or on the Atlantic or Pacific borders of the New World.

A rapid and too cursory inspection of the Whitney Glacier on Mount Shasta, of the moraines upon its lower extremity and of the ancient ones on the flanks of the mountain, which have been in part described by Mr. King, though much still remains to be studied, has enabled us, as never before, to comprehend the peculiar features in the system of ancient modified moraines of Central and especially Southern New England, including Nantucket, Martha's Vineyard, and the Elizabeth Islands. It seems to us plain enough that the ridges, or osars, and tumuli of gravel, as well as the sudden depressions among them, so frequent in New England, particularly about Salem and Andover, Mass., and in Maine, are of direct glacial origin.

The ascent of the crater cone of Mount Shasta was made during a short stay at Sisson's Station, at the base and to the southwest of the mountain, under the guidance of Mr. J. H. Sisson, who as the former guide of Mr. King and others was familiar with the moraines and glaciers of this magnificent peak. Never had I seen such a pure mountain form, chiseled out by the subterranean forces. No mountain, so far as we know, in Europe or America north of Mexico approaches it in its treble qualities of isolation, its regular conical form, and great altitude. Its summit for about four thousand feet is in large part covered with snow fields, and three glaciers, the Whitney, McCloud (on the eastern side), and Ash Creek (on the northeast), descend its flanks to or near the timber line, which is at an elevation of about nine thousand feet. I afterwards, in Oregon, had distant views of Mounts Hood, Adams, and St. Helens, members of the same family of extinct volcanoes, which form snow-capped, isolated cones rising about eight or nine thousand feet above the Cascade Range, which seemed dwarfed by their presence. I ascended the crater cone of Shasta by the trail leading from Sisson's hotel, and descended the eastern side to a point immediately overlooking the Whitney Glacier, which is about three miles long and extends from the summit of Shasta Peak down to or quite near the line of trees. With a good glass I could study the surface of the glacier for its whole length. The following account of the moraines and glacial marks is taken nearly as I wrote it down on the spot: —

August 25th we camped at the foot of the crater cone, and after a clear, cold night, the ice forming nearly an inch thick, we made an early start and reached the summit of the crater before nine o'clock. Here a magnificent view was spread out at our feet.

To the northwest lay the Siskiyou Range and Pilate's Knob, to the west the serrated range of the Salmon Mountains, while to the south rose to the altitude of about twelve thousand feet Lassen's Peak, its snow-clad summit glistening in the sun. The eye also ranged northeasterly over the lava plains, where the Modoc war formerly raged, and over the Klamath Lakes and Tule Lake. At our feet yawned the crater, about a thousand feet deep, its rim guarded by sharp, jagged pinnacles, while immense snow fields ran down to the bottom, in which lay two small frozen lakes.

On reaching our point of view overlooking the glacier, Mr. Sisson, who though he has observed the glacier for many years, had not now seen it for four years, remarked that it had diminished very considerably, the surface appearing at least seventy-five or one hundred feet lower than when he saw it four years previous. The glacier lies in a gulch on the north side of the mountain, and heads in a field of snow, or *névé*, which Mr. Sisson told me was continuous with the McCloud Glacier. The upper end must be over 13,500 feet in elevation. The surface is white and clean near the top. Ice cascades and crevasses begin very near the upper termination. On the upper portion on the east side, under a perpendicular wall of rock, is a lateral moraine, and a little farther down, where the glacier abuts against the crater cone, is a lateral moraine on the west side. The eastern lateral moraine ends in three ridges of dirt and loose masses of rock, and the terminal moraine covers the bottom of the glacier and connects the two lateral moraines. The end of the glacier, instead of being free of detritus, pushing the mass before it as in most European glaciers, runs under the terminal moraine for a considerable distance, the ice here and there projecting above the surface of the moraine. When these should melt away hollows would be formed, like those seen in the ancient moraines about Salem, Mass., and Southern New England. Large, angular bowlders lie scattered over the lower part of the glacier. The glacier extends nearly to the timber line, and seemed by a rough guess to be about three miles long. At the middle of the glacier the walls of lava rock are but slightly worn by the ice, owing to the hardness of the rock, and no grooves were to be seen. The glacier, judging by the frequent explosions, was in motion.

At and beyond the end of the present terminal moraine lies the former extension of it, constituting naked plains ; and below, the still more ancient moraine, showing the former size of the glacier, and comprised of a series of well-wooded hills. A muddy stream with a white bed and banks runs north into Shasta Valley from the end of the glacier. Near the termination of the glacier on the northeast side are three well-marked old naked moraines, at least two miles long, sweeping around to a small extinct volcano perhaps one thousand feet in height, ending in nine or ten small cones. These moraines apparently connect with the terminal moraine of a small, narrow glacier just east of Whitney's, and which must formerly have made an upper eastern branch of it. As evidence of the former extension of the glacier down into the Shasta Valley are two well-rounded hills, evidently regularly moulded by ice, and forming flattened domes.

The trail from the cone to Sisson's house lies over a lava ridge, formed of loose, angular bowlders of the reddish lava composing the cones, with a few bowlders of a whitish rock. For several miles it was arranged in transverse terraces or benches a few feet in height, with rock masses piled upon them in slightly concentric parallel transverse rows, the interspaces being clear of rocks. It extends about eight miles from the base of the cone down into the forest, and is so irregular, rough, naked, and jagged that Mr. Sisson has well christened it the "Devil's Garden." At first it seemed to me to be simply an old lava stream, like those I had seen on Mount Vesuvius ; but after riding several hours over and past it, both on my way to and from the cone, and noticing the foreign bowlders on its surface, and two lateral moraines on the sides, it seemed without doubt to be a long, narrow, median moraine. For the greater portion of its length the sides are remarkably steep and regular, and it has a remarkable external resemblance to the gravel ridges in Andover, Mass., and other portions of New England.

To the southward, between the cone and the main peak, is a small park in which a glacier must formerly have rested ; on the outer western edge is a small terminal moraine, flanked by a lateral moraine on each side.

As the crater cone is composed of a light reddish lava, while the much older main peak consists of a pale, bluish-gray trachyte, it is easy to distinguish the respective origins of the long lateral moraines which extend from the two peaks, the last red lava ridges extending down from the crater cone, lying parallel to the northwesternmost pale gray moraine of the main peak. The trachyte moraines even extend ten or twelve miles down to the west side of the stage road a little north of Sisson's hotel, where there are several conical hills of *débris*, which had evidently come from the main peak of Mount Shasta.

The fact of most interest connected with the Whitney Glacier is that the ice is concealed for a considerable distance by the terminal moraine, and that by the melting of the ice the hillocks would not only remain, but deep hollows would be left. Now we have precisely the same contour of the surface over a large part of Essex County, Mass., particularly about Salem and on the islands on the southern shore of New England. The peculiar scenery about Salem and Andover, and on Naushon Island, Martha's Vineyard, etc., can be fully explained by a reference to the terminal moraines on the glaciers of Mount Shasta, as in fact has been done by Mr. King.[1] Again, I believe the so-called *kames*, *osars* or *eskers* of New England, such as Indian Ridge in Andover, Mass., and similar horsebacks in the White Mountains and in Maine, which I have examined, are much like the long, slender ridges of gravel and bowlders which lie on the flanks of Mount Shasta. Without much doubt the bulk of the glacial drift of the Northern Atlantic States was ground-moraine material, while a large proportion formerly covered the ice sheets, often thin and broad, which spread out over the hilly portions of the country; and the gravel ridges or eskers were lateral moraines, though perhaps also in part terminal, which have been partly rewashed by fresh or salt water.

Very interesting moraines were again seen on both sides of the stage road in Butteville, Shasta Valley. A remarkable one, evidently derived from the crater cone, and which must be ten or fifteen miles in length, is composed of small bowlders of reddish lava, arranged in transverse rows, with clear interspaces, the ridges not being more than a foot or two high, the bowlders being much smaller and less angular, having traveled farther than those in the Devil's Garden.

The glacial phenomena about Puget Sound and the southern extremity of Vancouver Island, about Victoria, were of a high degree of interest. Leaving the Columbia River at Kalama the Northern Pacific runs through a broad, park-like valley covered originally with pine forests, the valley widening towards Tacoma, at the head of Puget Sound, the surface being flat or undulating, with quite well-marked moraine hills and gravelly ridges, resembling those in New England. This region, like the New England coast, has been under the sea, and the waters of Puget Sound have washed and rewashed the original moraines, so that the scenic features are strikingly similar to the familiar plains and fields and ridges about Boston and Salem, as well as Southern

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[1] Mountaineering in the Sierra Nevada, 1872; and Some Remarkable Gravel Ridges in the Merrimac Valley, by Rev. G. F. Wright, 1877.

Maine. Here, evidently, the moraines had come down on glaciers from the Cascade Range, the source mainly perhaps from Mount Rainier, now a lofty, snow-clad cone like Mount Hood.

The former glaciers about Puget Sound were apparently a part of the series now existing in Alaska and described by Mr. W. H. Dall. Along the railroad track, within eight or ten miles of Tacoma, was a series of twelve or fifteen low, gravel ridges as level and with as regular a slope as fortifications. They run north by east and south by west, in a course generally parallel with the Cascade Range. I could not but compare them with the series of transverse ridges on the Mount Shasta moraines, and regard them as marking the steps in the retreat of a broad, thin mass of ice extending into one of the arms of Puget Sound from the neighborhood of Mount Rainier.

The shores of Puget Sound from Tacoma to Port Townsend are lined with a series of sands and gravels capping marine clays, in all respects like the cliffs of Massachusetts Bay and the Maine coast; and indeed the scenic features of Puget Sound with its many long, narrow reaches recall the lakes of Maine and Southern Norway. But at Vancouver Island, the resemblance is still more striking. Here the rocks in several localities about Victoria, on the shores of the Straits of Fuca, are as deeply furrowed and scored as I have seen anywhere on the coast of New England or of Norway. The trap and syenite down to the water's edge are smoothed and polished, with often deep furrows several inches wide, all running north 10° west, and south 10° east. The glacier which made them must have come from the centre of Vancouver Island, which is high and mountainous. Particularly interesting was the presence of fossil quaternary shells in the clay which covered the rocks, and which in color and scenic features exactly reproduced that formation, so familiar to me on the coast of Maine.

The clays were fine, stratified, though perhaps less so than Atlantic coast clays, with bowlders, mostly angular, but some well scratched and glacier-worn. These beds graduated above into regularly stratified pebbly, or gravelly, or sandy beds capped by black mold containing Indian shell heaps. The fossil shells and barnacles occurred from two to ten feet above the sea level. The species obtained were submitted to Mr. R. E. C. Stearns of the University of California, who kindly named them for me. They are enumerated in accordance with their relative abundance, the *Cardium corbis* being by far the most common.

Cardium corbis Martyn. Now a common Pacific coast shell.
Schizothœrus Nuttalli Conrad, " " " "
Purpura crispata Chemnitz, " " " "
Mytilus modiolus Linn., " " " "
Leda fossa Baird. One perfect example.

The valves of an enormous barnacle (probably *Balanus tintinnabulum*) frequently occurred. It lives abundantly on the rocks about Victoria.

Glacial phenomena of quite a different nature were observed in the Yosemite Valley. From a hasty examination of the valley and its surroundings from Glacier Point, as well as different localities in the valley itself, it seemed plain enough that the valley, originally due to a series of faults as described by Professor Whitney and Mr. King, had become filled with ice continuously with the upper valley, as high up at least as the summit of Mount Starr King, which is a rounded dome; the source of the supply being the high peaks of the Sierra, such as Mounts Dana and Lyell, which are jagged and not molded by ice, all the peaks below having been rounded and worn by ice, while the sides of the valley in the more exposed places, and the North Dome and Half Dome, have been, as described by Mr. John Muir, molded and smoothed by the ice. The walls of the outlet, or lower valley, seemed also to have been molded by ice.

The history of the valley appeared to us somewhat in this wise: After its present shape had been marked out, and the mountains round about had assumed their present shape, the result of atmospheric erosion during the later tertiary period, the climate changed, the Sierra was covered with glaciers, and the Yosemite Valley was filled to overflowing with ice. It melted, and filled the bottom of the valley, which now forms a level park. The small, low, terminal moraine at the lower end of the valley, which formerly dammed the Merced, was finally cut through by the river and the park drained, and the present aspect of this wonderful cañon succeeded. This is the history of many valleys which I have seen in New England, Labrador, and Scandinavia, and the parallelism between them seems remarkably exact.